Trajectory-Oriented Operations with Limited Delegation: An Evolutionary Path to NAS Modernization

Thomas Prevot, Todd Callantine
San Jose State University/NASA Ames Research Center, Moffett Field, CA

Parimal Kopardekar, Nancy Smith, *Everett Palmer, Vernol Battiste*
NASA Ames Research Center, Moffett Field, CA

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- NAS modernization is progressing
  - RVSM, ERAM, ADS-B / CPDLC

- Some Far-term concepts target 2 to 3 times current day capacity by offloading separation task from air traffic controller
  - Advanced Airspace Concept: Separation maintained by ground automation
  - Autonomous Operations (e.g DAG-TM CE5): Separation maintained by pilots

  Both use time-based traffic flow management, focus on absolute trajectory-based operations and need to exchange trajectories and states quickly and frequently

- Some near-term concepts integrate Airborne Separation Assistance Systems to improve throughput and reduce controller workload
  - Eurocontrols Co-Space
  - DAG-TM CE11: Spacing and Merging in Terminal Area

  Near-term ASAS applications focus on relative aircraft-to-aircraft operations and delegate additional tasks to the flight crew

- Proposal:
  - Combine the common elements of the far-term trajectory-oriented approaches and integrate the near term ASAS application
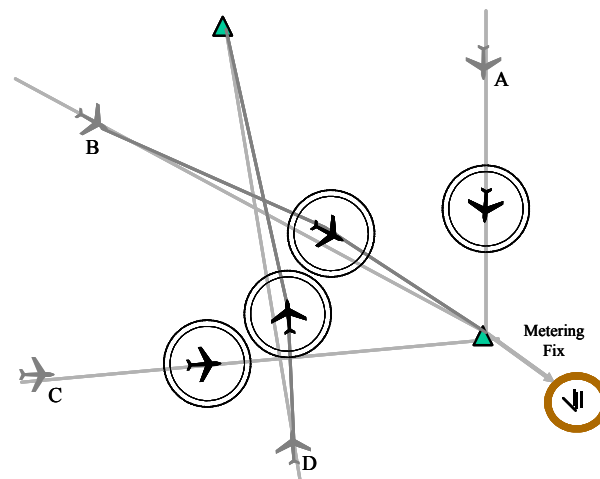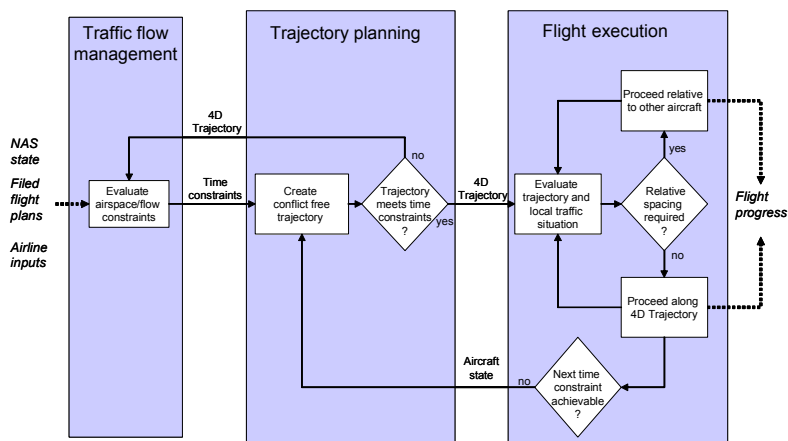
Concept

- *Use time-based flow management to regulate traffic density,*

- *Use trajectory-based operations to create efficient, nominally conflict-free trajectories that conform to traffic management constraints and,*

- *Maintain local spacing between aircraft with airborne separation assistance.*

Trajectory Oriented Operations with Limited Delegation
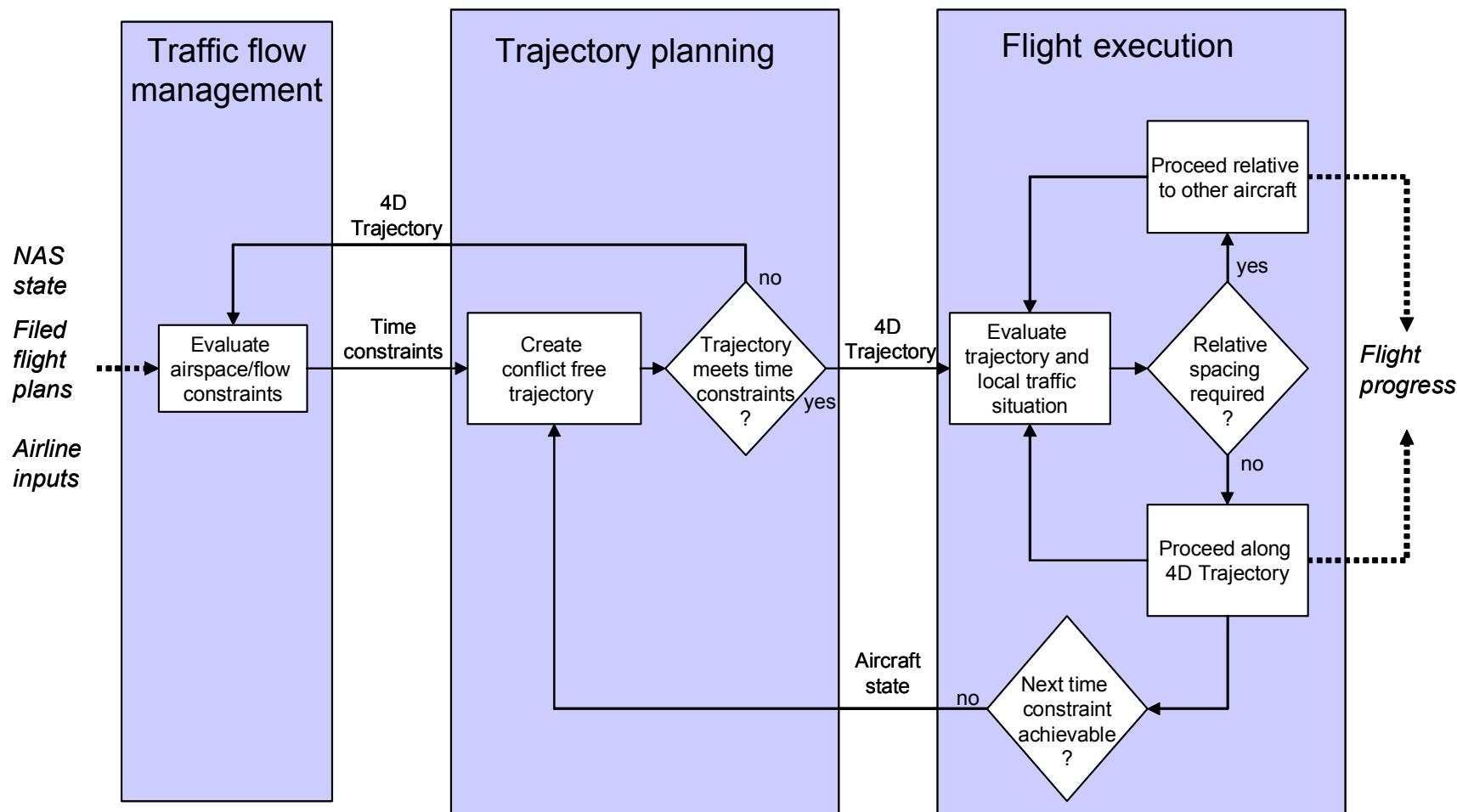
Proposed system: time-based traffic flow management and trajectory-orientation are augmented by a tactical relative spacing loop. Feedback between the layers is event-driven and not continuous.

- Time-based traffic flow management on a NAS-wide and local level assures that local airspace areas are not overloaded at any given time

- Trajectory-based operations are used to plan and execute conflict free flight paths for upcoming flight segments.

- Together, these operations put flight crews in a position to utilize Airborne Separation Assistance Systems (ASAS) to deal with local spacing issues, if instructed or permitted by the controller to do so

	Current day			Medium-term Integrated Air/Ground System		
	TFM/AOC	**Controller**	**Flight Crew**	**TFM/AOC**	**Controller**	**Flight Crew**
Traffic flow management	Miles-in-trail-constraints			Time-constraints		
Flight planning	Filed flight plan	Flight plan amendments		4-D Trajectory	Trajectory changes	
Schedule management	Meter list	Sequencing and delay absorption with 1 minute tolerance		Scheduled times of arrival (STA)	Meet STA with 15 seconds tolerance	
Strategic conflict prevention		Route/altitude segregation			Trajectory de-confliction,	
Delay absorption techniques		Holding, vectoring			Holding, Trajectory changes, RTA to aircraft	RTA compliance
Separation management		Vectoring			Vectoring, delegation of spacing to flight crew	Monitoring or executing spacing,
Flight path management		Off route vectoring, back to route via known waypoints			Trajectory changes	Trajectory requests possible
Primary flight mode in congested airspace			Tactical, autopilot			FMS engaged
In-trail-spacing and merging		Speed commands				ASAS spacing

- Available near-term technologies based on current modernization plans up to the year 2010
    - Improved surveillance data (ADS-B, terminal area radar quality)
    - Initial CPDLC functions (e.g TOC) from controllers R and D-side
    - Controller access to time-based metering and conflict probe
    - Most aircraft have FMS, some CDTI and ASAS-spacing capabilities

- Approach: introduce the concept procedurally
    - ground-based traffic flow management coordinated between airlines and air traffic service providers
    - definition of FMS procedures for air/ground coordination
    - schedule management with FMS compatible procedures by the controllers
    - delegation of spacing operations to flight crews of properly equipped aircraft
    - precise management of spacing using improved surveillance data and DSTs by controllers for unequipped aircraft

Near-Term: Increased use of FMS procedures

- FMS procedures enable trajectory coordination by voice

- Charted FMS procedures

- FMS compatible clearances e.g.
  "Cleared for Precision Descent at 310 knots"
  "Descent via FEVER transition to ILS18R
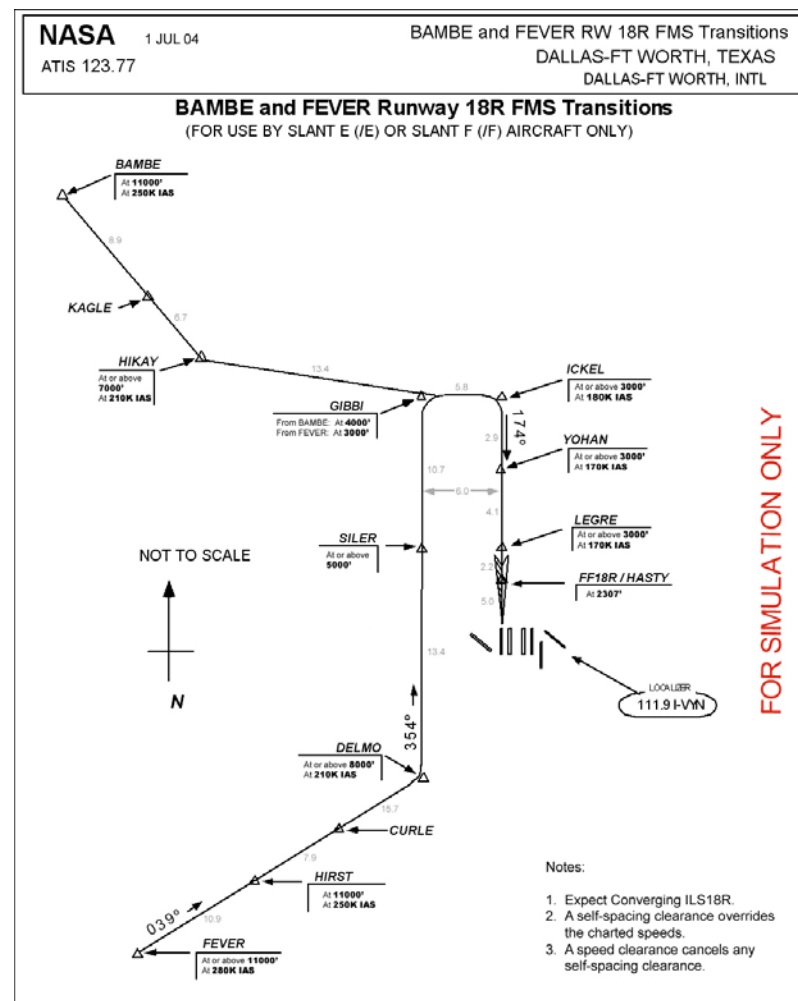
Use of FMS increases accuracy and supports trajectory-orientation

*Without data link integration limited to standard routes and named waypoints*

- Presentation of more precise meter information to controllers
- Timelines
- FMS compatible metering advisories (e.g. cruise/descent speeds)
- RTA assignment if aircraft is properly equipped
- Responsive trial planning with meter information
- Possibly conflict free metering advisories (e.g. CTAS EDA)
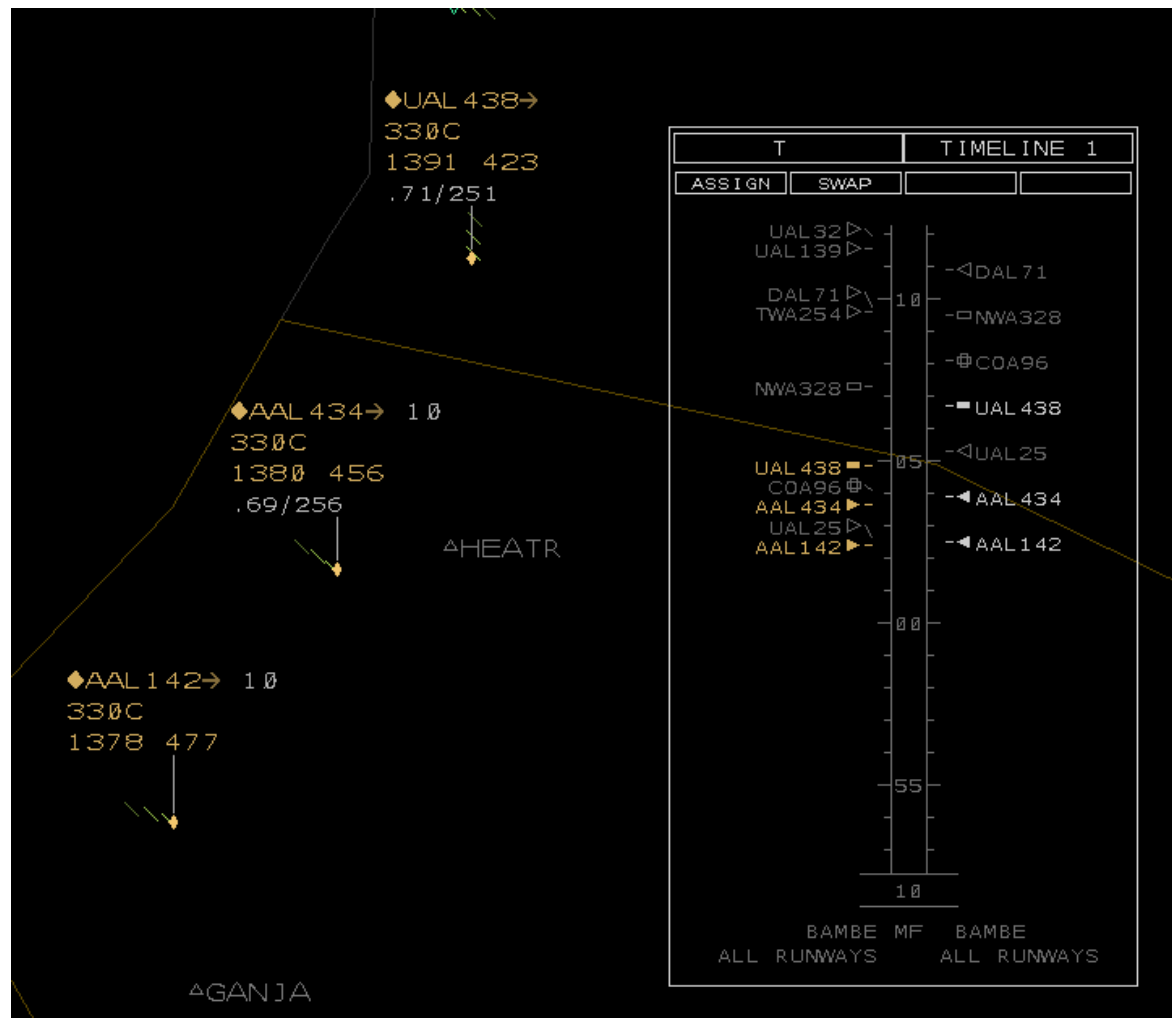
*Increases delivery accuracy at meter fixes or runways*

Workload shift from low altitude to high altitude controllers

- Integrate trial planning with metering information and conflict feedback
- Needs to be highly responsive to be acceptable
- Free-route trial planning difficult without data link integration
- Initially use in low to moderate traffic to gain experience
- URET and CTAS D2 tools
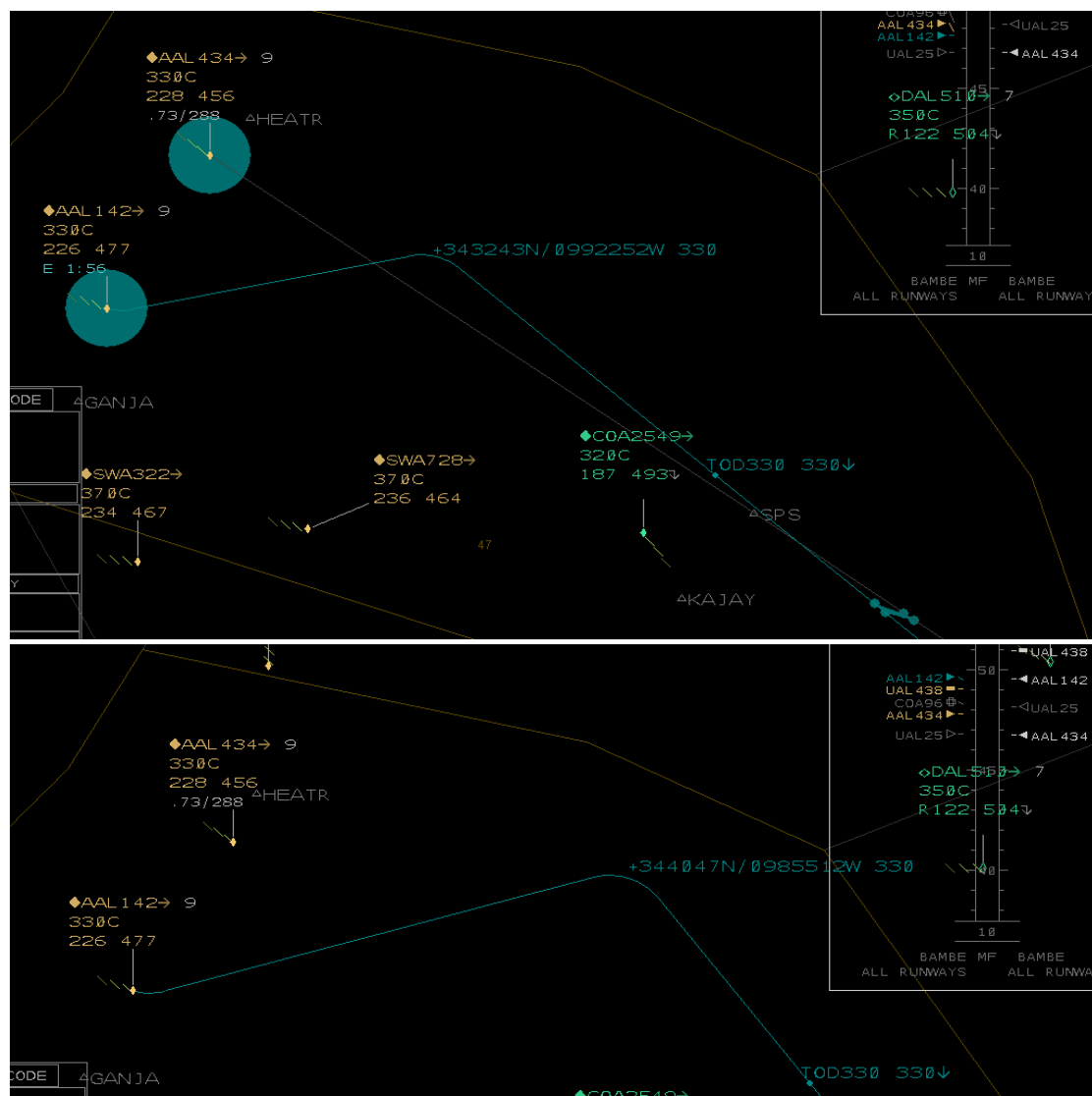
Trial planning is most powerful when integrated with data link
Can be used in the near-term workload permitting at controllers discretion
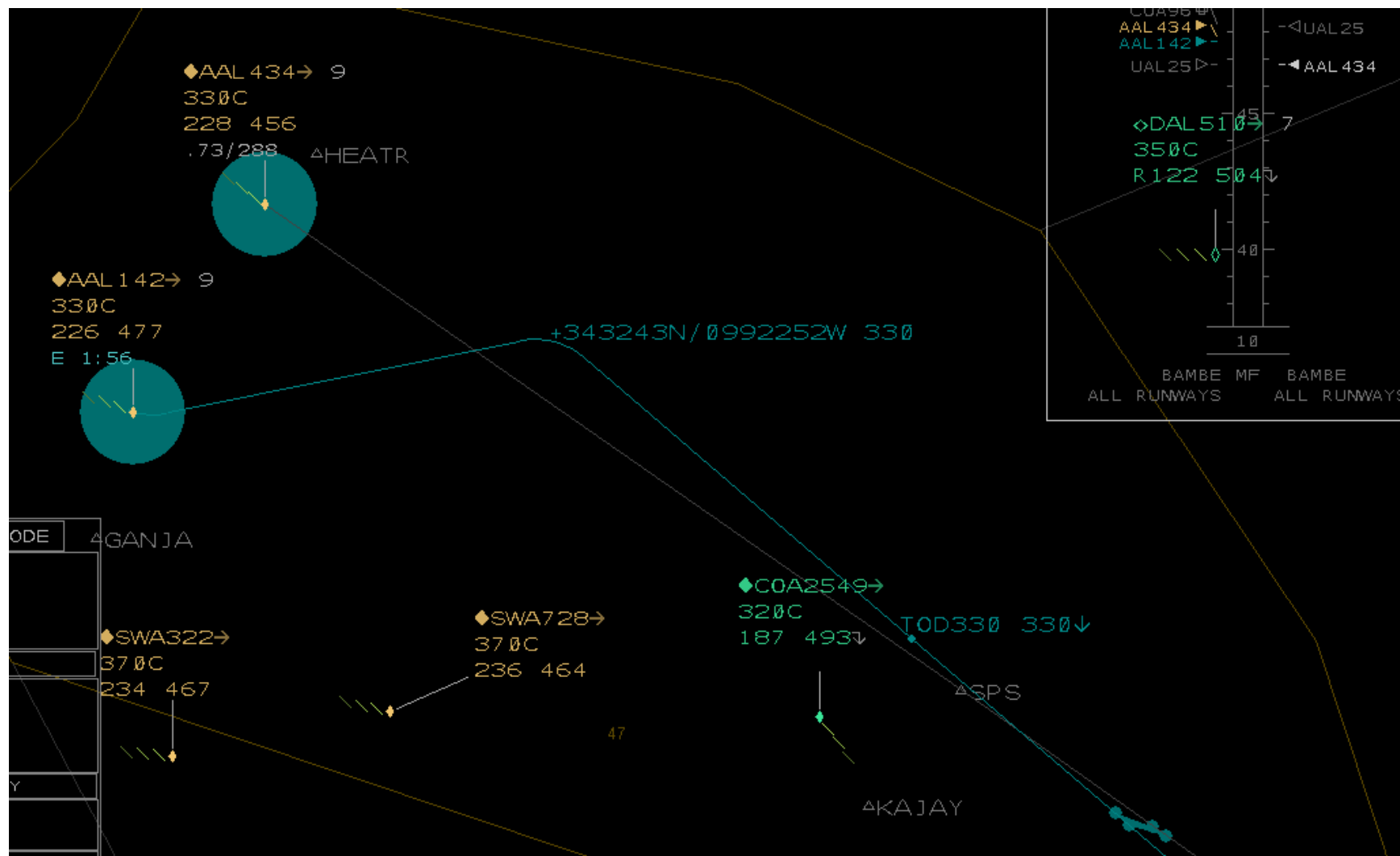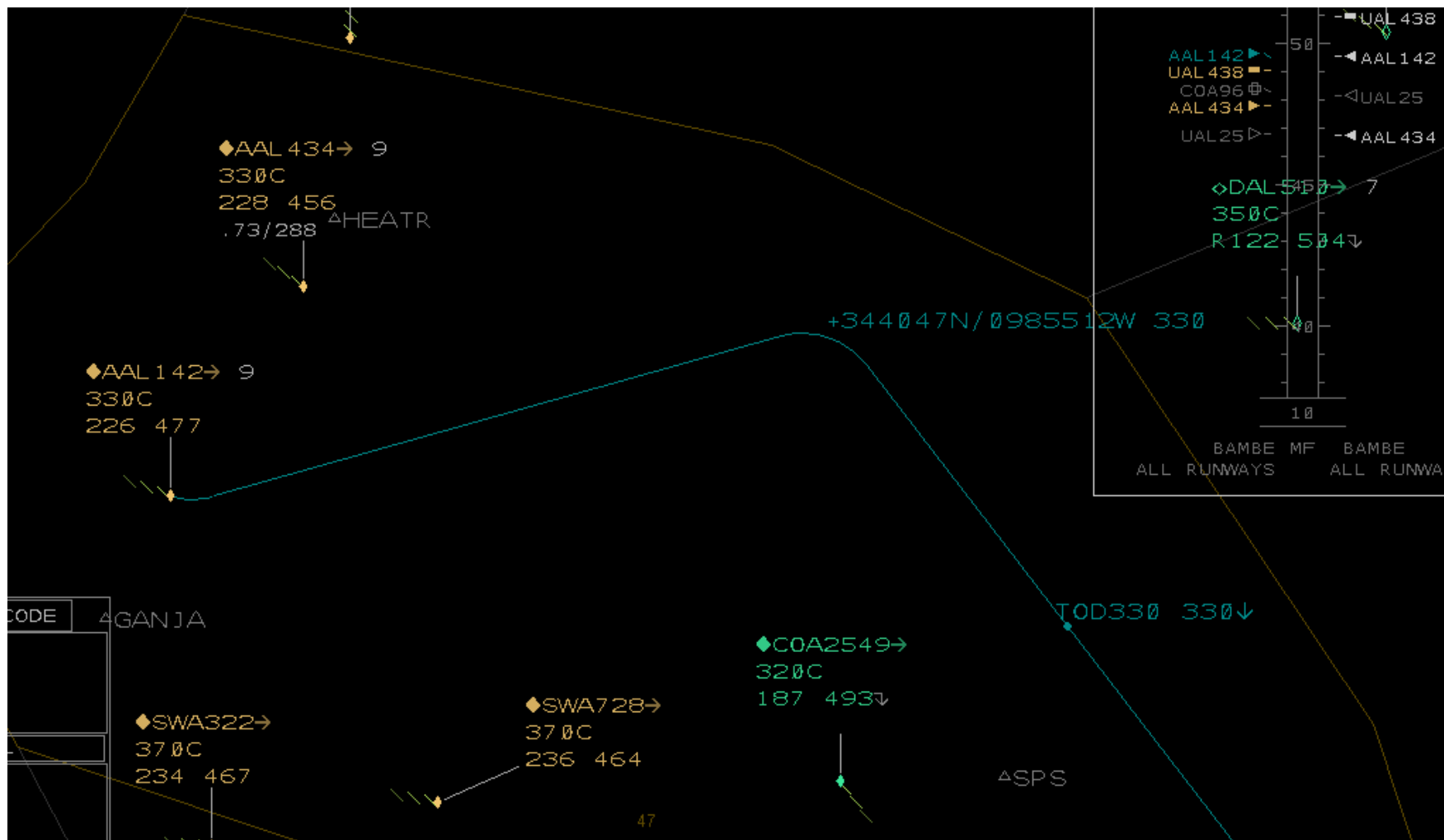
- Altitude trial planning can be integrated into DSR framework in the near-term

- Trajectory and delay feedback can be provided

- New cruise altitudes can be communicated by voice or data link

- Flight crew procedure to enter into FMS is straightforward
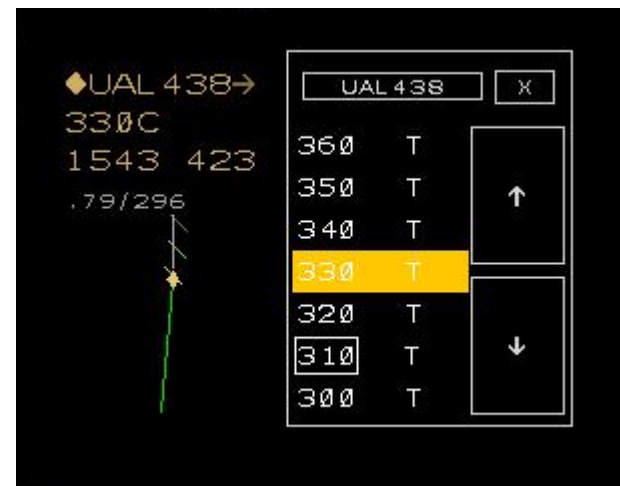
- Spacing operations can be delegated to ASAS equipped aircraft

- Controllers can use the improved surveillance to monitor equipped aircraft and control unequipped aircraft more precisely

Approach controller display
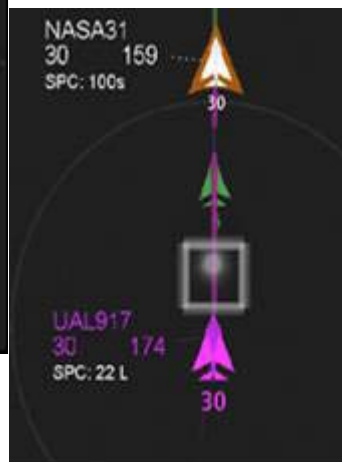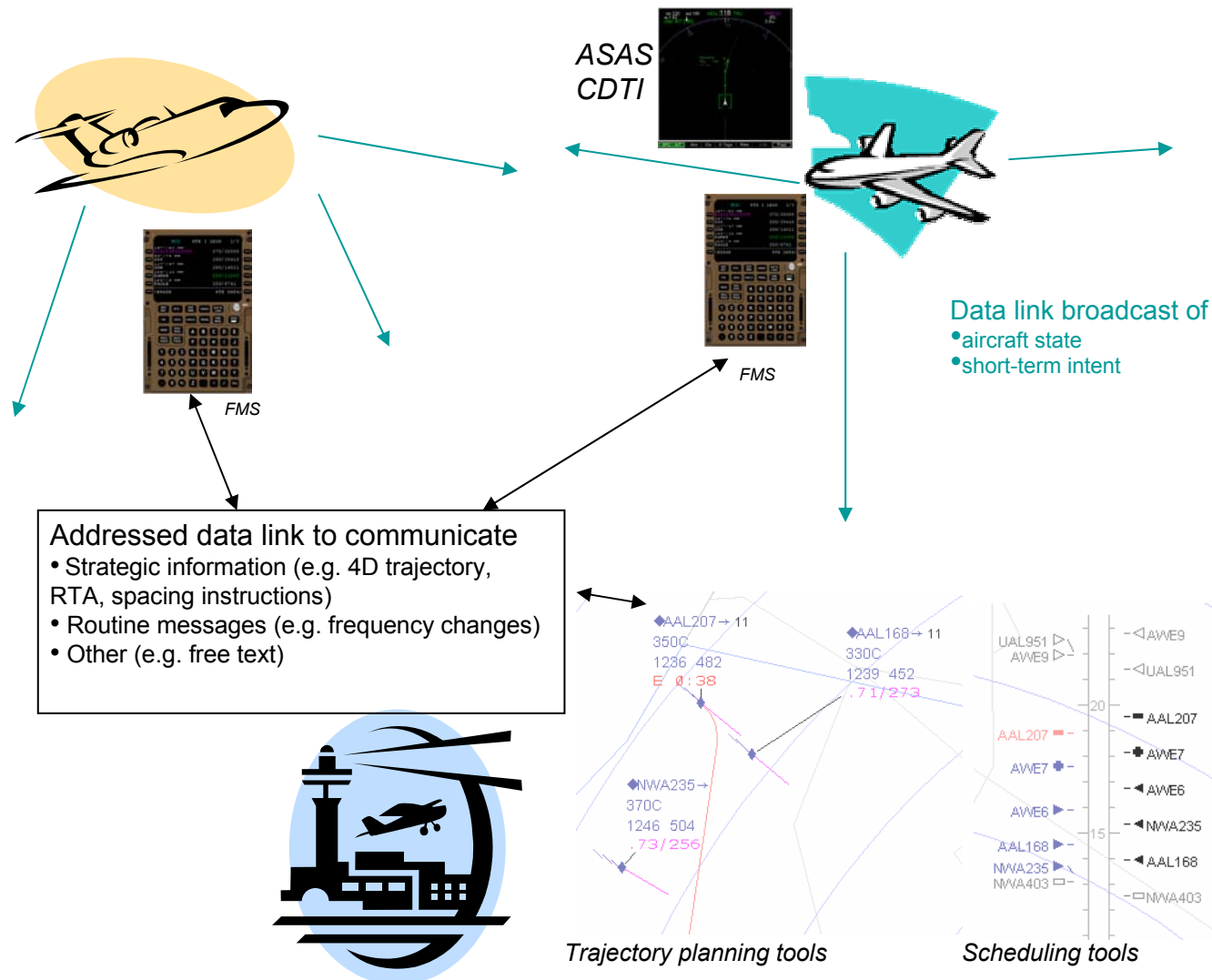

Flight deck display

Benefits in light of the future evolution

- Phase-in the concepts of trajectory-oriented operations and limited delegation of spacing tasks in a safe operational environment
- Controllers and pilots can gain experience with new roles without changing responsibilities
- Advance ground-based automation to be equivalent to flight deck automation
- Use current flight deck automation more efficiently
- Phase in new flight deck capabilities

Immediate benefits

- Increased delivery accuracy at meter fixes and runways
- Improved flight efficiency (less excess vectoring or low altitude flight operations)
- Workload reduction for controllers working traffic bottlenecks
- Reduced excess spacing and higher throughput in terminal areas

- Technological integration of advanced air and ground automation

ASAS
CDTI

Data link broadcast of
- aircraft state
- short-term intent

FMS

FMS

Addressed data link to communicate
- Strategic information (e.g. 4D trajectory, RTA, spacing instructions)
- Routine messages (e.g. frequency changes)
- Other (e.g. free text)

*Trajectory planning tools*

Scheduling tools

- Air traffic service providers equipped with decision support tools for scheduling and trajectory planning.

- Aircraft equipped with Flight Management Systems

- Addressed data link communication between ground-based decision support tools and FMS to exchange strategic information and routine messages between controllers and pilots

- Data link broadcast from the aircraft to provide up-to date state and short term-intent information to the ground and other aircraft

- Airborne separation assistance systems (ASAS) and cockpit displays of traffic information (CDTI) on the flight deck with trajectory planning tools

- Two types of information required:
  - Frequent state information (~every second)
  - Up-to-date trajectory and short -term intent information

- Ground system needs FMS trajectory for planning, scheduling and medium to long range conflict probing
- Flight control system targets required for early detection of non-compliance and short-range conflict probing
- ADS-B has bandwidth and range limitations
- Addressed data link (e.g. FANS) has latency problems

- Approach:
  - Communicate aircraft state and flight control system targets frequently via ADS-B
  - Communicate FMS-trajectory via addressed data link whenever it changes
  - Initial ASAS spacing applications can be done with short-term information available via ADS-B
  - More advanced trajectory-based flight deck applications can retrieve other aircraft trajectories via addressed data link

Message Type	Message Text	Loadable content	Controller procedure	Flight Crew procedure
Transfer of Communication (TOC)	CONTACT / MONITOR <frequency>	None required	If TOC Auto selected, occurs automatically when handoff accepted by next sector, or use command "UF"	Accept message, Select new frequency, contact or monitor new frequency
Route uplink	REROUTE TO <waypoint>	Location of new points (named or latitude/longitude), and /or altitude/speed restrictions	Create route trial plan then use command "UC"	Load message content, review uplinked route, accept or reject message, Execute
Cruise Altitude uplink	CLIMB/ DESCEND AND MAINTAIN <flightlevel>	Cruise altitude	Create altitude trial plan, then use command "UC"	Load new cruise altitude, review new trajectory, accept or reject message, Execute or Erase
Cruise/Descend Speed Uplink	DESCEND AT <mach/cas>	Cruise mach or cas and descent cas	When speed advisory appears in fourth line, use command "UC"	Load new cruise/descend speed, review new trajectory, accept or reject message, Execute or Erase
RTA uplink	RTA AT <waypoint> : <UTC time>	RTA waypoint, RTA (UTC)	When "UPLK RTA" appears in fourth line, use "UC", use "UR" anytime RTA has been assigned	Load new RTA, review new trajectory, accept or reject message, Execute or Erase
Spacing uplink	e.g. FOLLOW <callsign> AT <time> Seconds	Lead aircraft, spacing interval	When spacing advisory appears in fourth line, use "UC", use "US" anytime lead and time have been assigned	Select target on CDTI, select interval, review acceptability, accept or reject, engage or de-select target
Free Text Uplink	e.g. CHECK STUCK MIKE	None	Use command "UT" and type text or select from predefined Menu Text options	Read message and deal with it
Downlink of new route request	REQUEST REROUTE TO <waypoint>	New trajectory	See pending request in portal, click on portal to open request in trial planner, accept or reject request with "UY" or "UN"	Create route on CDTI or FMS downlink request, wait for response, execute or erase modified FMS route

One action loading by flight crew

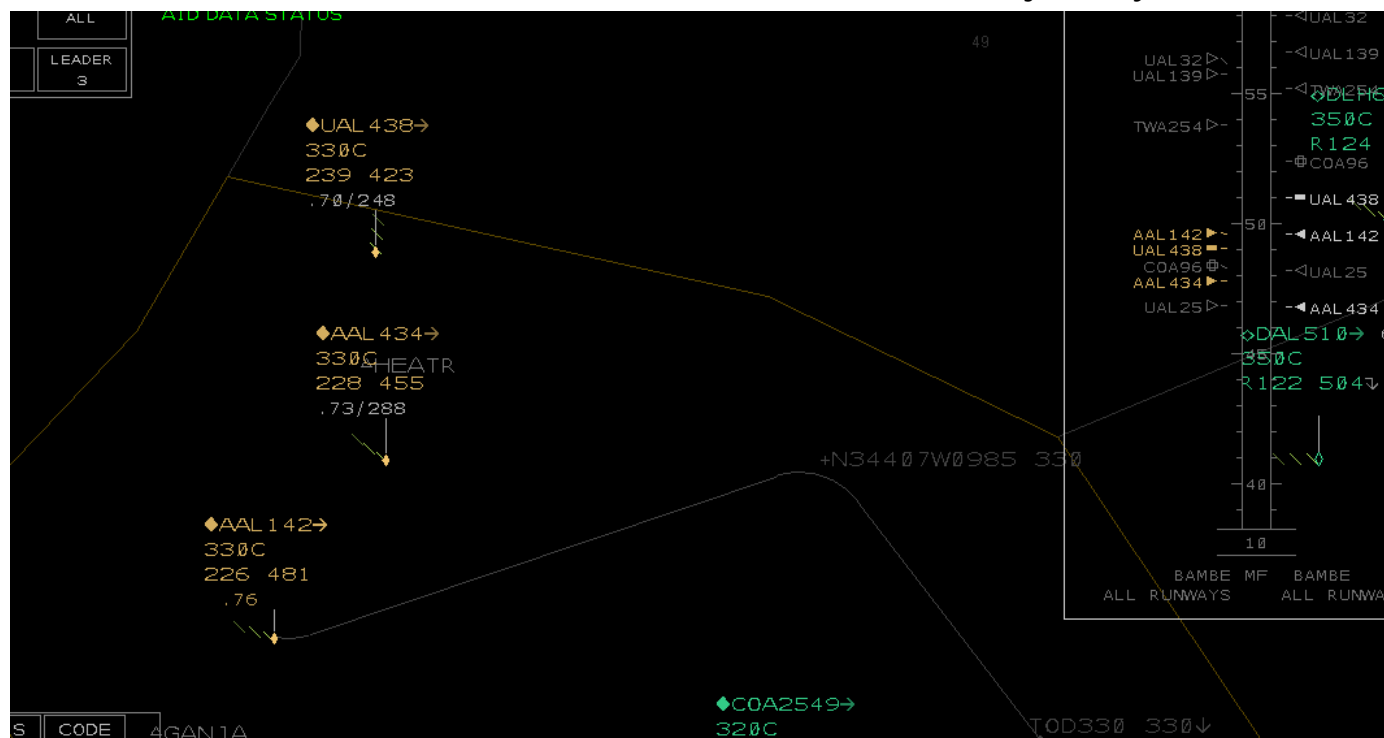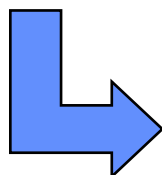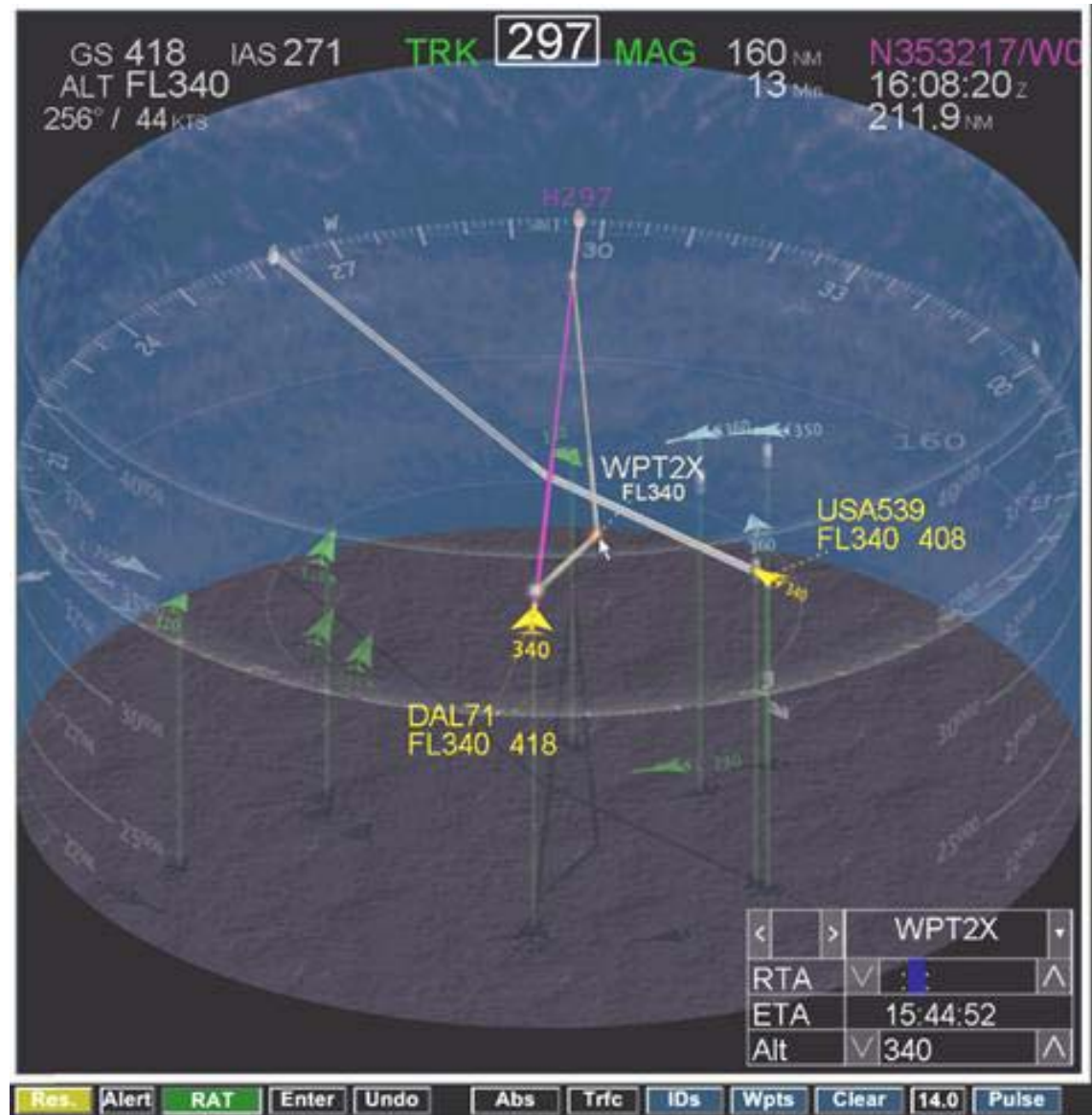*One action trajectory uplink by controller*
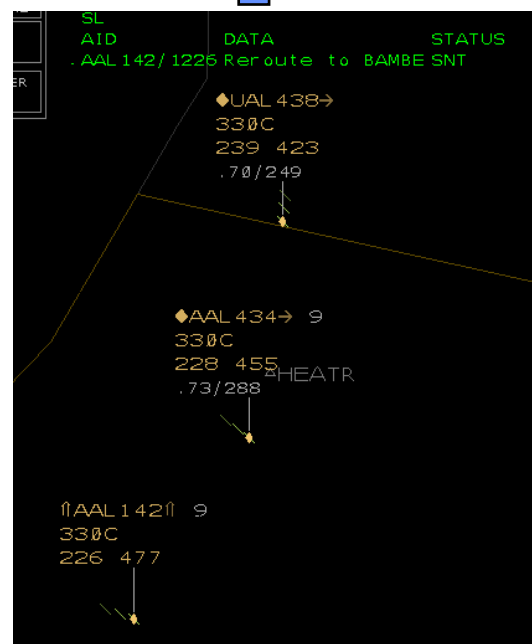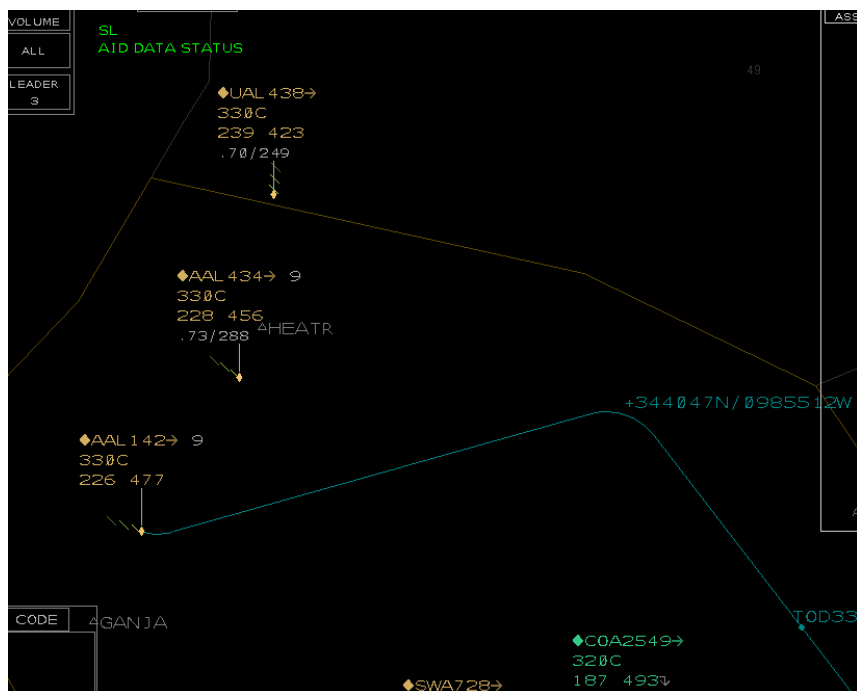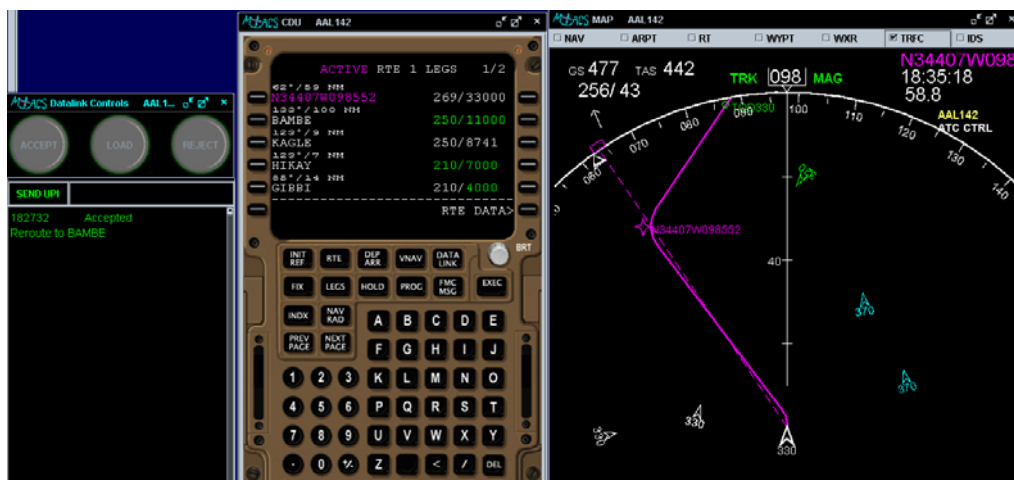
execution by flight crew triggers new FMS trajectory downlink
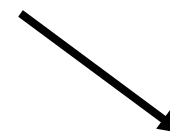
Controllers can review new trajectory

- Advanced CDTI can integrate trajectory information of own ship and other aircraft and flight crew can review trajectory uplinks or downlink requests for controller approval

Benefits in light of evolutionary path

- Full procedural and technological integration of air and ground to enable far-term concepts
- Pilots and controllers have access to all relevant trajectory and traffic information
- Powerful tools to modify and communicate trajectories in the air and on the ground
- Airborne and ground-based tools to fine-tune relative spacing
- Controllers and flight crews have experience with delegation of new tasks like spacing

Immediate benefits (demonstrated in recent simulations)

- En route sector capacity increase of at least 50 %
- Almost complete elimination of aircraft vectoring
- Highly improved flight path predictably -> major security benefit

Medium-term: Air Traffic Controller feedback

| Question	Range	Low Altitude controller	High Altitude controller #1	High Altitude controller #2	En route controller		Average
How useful was the ability to obtain speed advisories when trying to deliver aircraft to a meter fix STA?	extremely useful (5) not very useful (1)	5	5	5	N/A		5
What impact do you think the ability to datalink clearances had on your overall workload?	greatly reduced (5) greatly increased (1)	5	5	4	N/A		4.67
How effective were cruise and descent speed clearances for controlling arrival traffic compared to current operations?	much more effective (5) much less effective (1)	4	5	4.5	N/A		4.5
How effective were trial plan route amendments compared to vectoring used in current day operations?	much more effective (5) much less effective (1)	5	5	5	4		4.75
How effective were trial plan altitude amendments compared to current day operations?	much more effective (5) much less effective (1)	3	5	5	4		4.25
How useful was the ability to datalink clearances compared to voice clearances?	much more useful (5) much less useful (1)	5	5	5	5		5

Medium term: Expected capacity benefits

- Average aircraft owned by sector controller and workload ratings (WAK) from 4 simulation runs using the medium-term system

- Current day nominal Monitor Alert Parameters (MAP):

AMA, ADM, SPS: 18

UKW: 15

Good potential for at least a 50% en route and transition sector capacity increase over current day
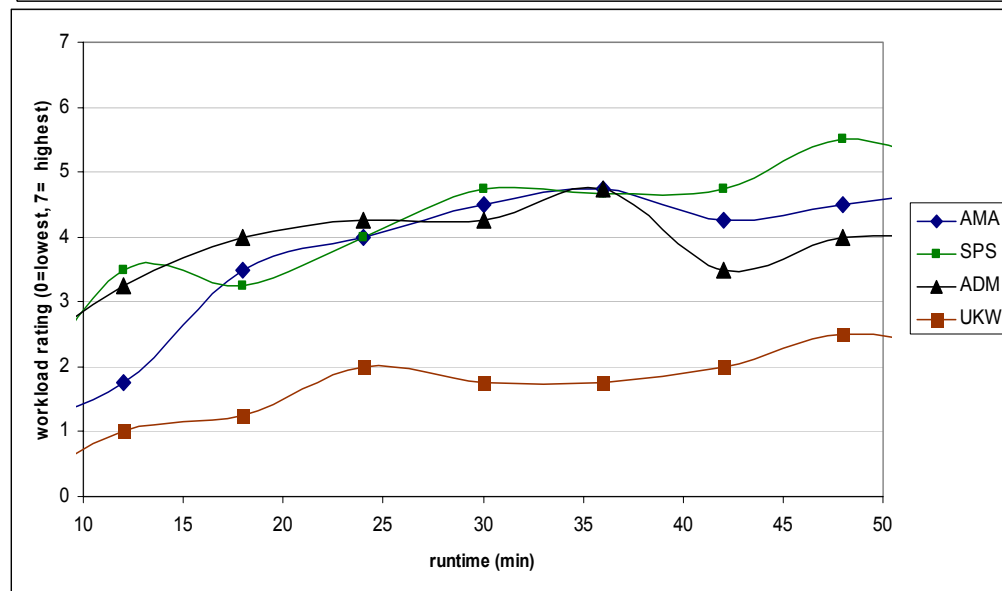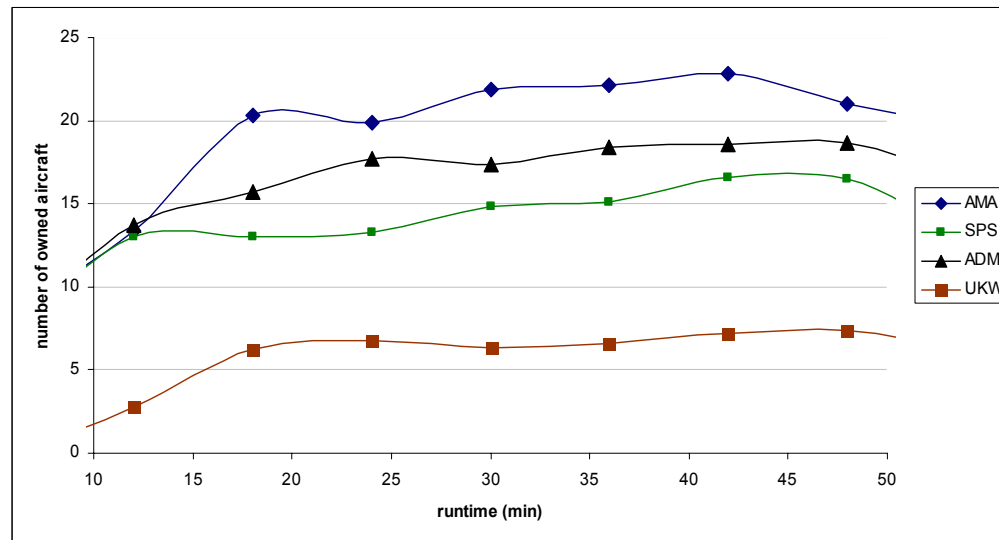
- Refining the medium-term concept with increased pilot involvement and additional automation
  - The medium-term concept may prove effective enough to support traffic demands even beyond the next twenty years without large paradigm shifts
  - Flight crews can become more involved in trajectory planning and delegation can have more degrees of freedom
- Advanced airspace concept
  - Uses a similar infrastructure
  - Controllers and pilots have had a chance to gain trust in automation to find it more acceptable
- Autonomous operations
  - Expansion of limited delegation of spacing tasks to full autonomous operations
  - Controllers may have gained trust in flight crews performing ATC operations; flight crews gained experience in ATC tasks

Far-term ATM may be a combination of various approaches

- Trajectory-oriented time-based arrival operations, data link, and spacing operations have shown potential benefits for capacity, security, efficiency, and controller workload

- For maximum benefits air and ground need to be well-integrated

- Trajectory-Oriented Operations with Limited Delegation can be applied to different phases of an evolutionary path

- Medium-term phase provides substantial benefits over current system and can be implemented in the next 10 to 15 years

- Baseline to be built upon if more advanced concepts are required in the far-term